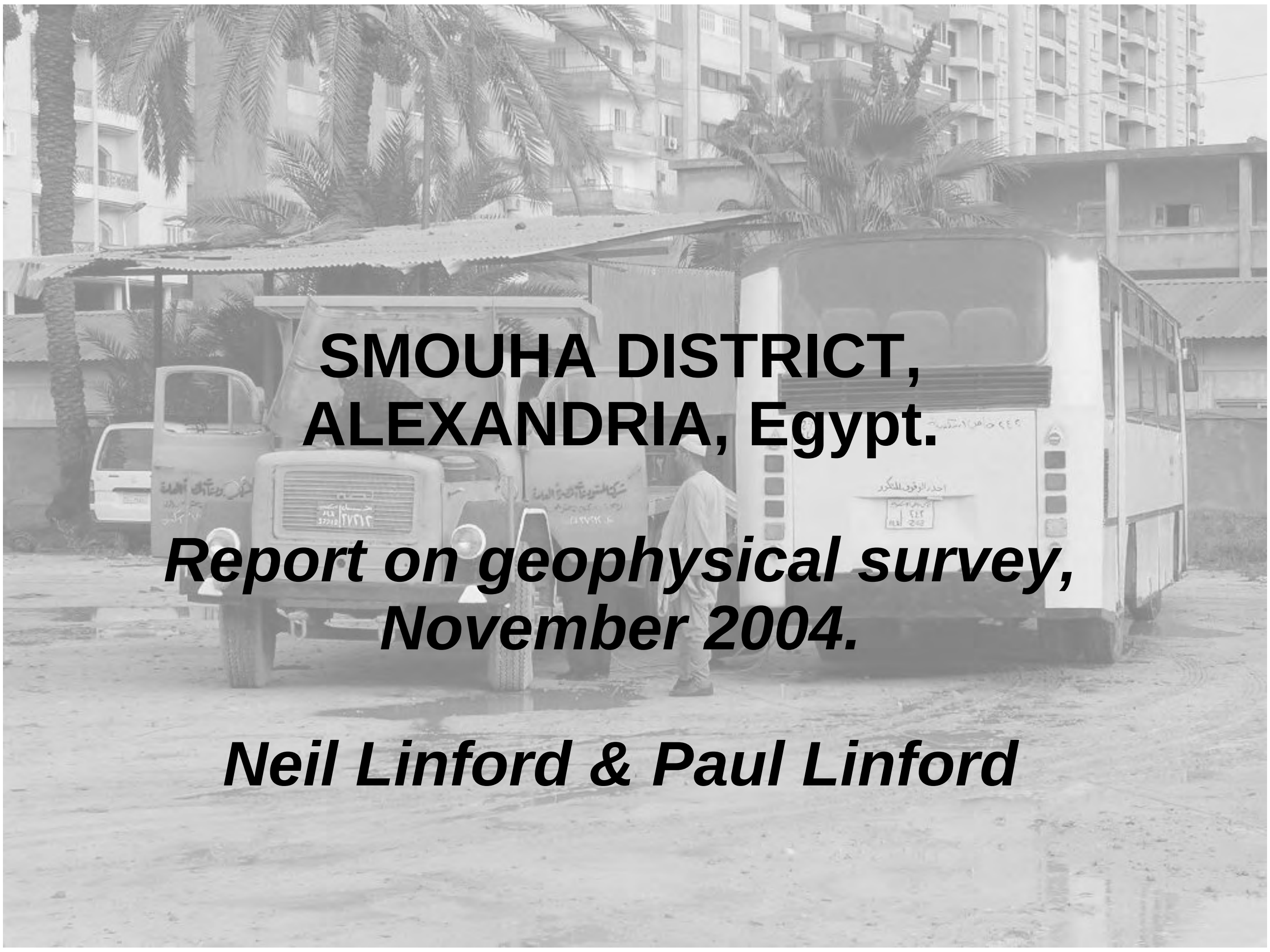

SMOUHA DISTRICT, ALEXANDRIA, Egypt.

Report on geophysical survey, November 2004.

Neil Linford & Paul Linford

SMOUHA DISTRICT, ALEXANDRIA, Egypt.

Report on geophysical survey, November 2004.

Summary

A geophysical survey was conducted over the suspected site of the remains of the sanctuary temple complex in the ancient district of Hadra, now the heavily developed Smouha district of Alexandria, Egypt. The location of the site was estimated from historic map regression that was tested in three key-hole areas of open ground where access for geophysical survey could be obtained, the Port Authority Bus depot, the Elabrahimia school for girls and the Ashraf el Khagha primary school. Both ground penetrating radar (GPR) and electromagnetic survey were used for the survey and identified a number of subsurface anomalies. Unfortunately, due to the limited area of open space available few of the anomalies were fully described by the survey and some may be discounted due to modern intervention such as the presence of buried services. The archaeological significance of the results is unclear and requires confirmation through invasive investigation to ascertain the full significance of the identified anomalies.

SMOUHA DISTRICT, ALEXANDRIA, Egypt.

Report on geophysical survey, November 2004.

Introduction

A geophysical survey was conducted to assist with a Cambridge University research project to locate the remains of the sanctuary at Hadra. Ruins at the site were still standing until at least 1872, when Mahmoud el Falaki described the ruins of a "..great temple… with water filling a slight depression". In 1842 Harris, the British consul, was described as owner of two of the statues from the sanctuary, representing Cleopatra VII and her son Ptolemy XV. In 1907 the leg and head of the male ruler was donated to the Greco-Roman Museum in Alexandria, and in 1912 Albert Daninos sold the upper section of the queen to the Royal Museums of Mariemont. . Further evidence for the location of the temple has been derived from historic mapping, in particular the map published in 1866 by Mahmoud el Falaki, that has allowed the approximate location of the site to be established through a detailed map regression conducted by the Centre D'Etudes Alexandrines (CEA). The site was last mentioned in 1922, when E.M. Forster mentioned that he passed the site between the Nouzhi gardens and Sidi Gabar station.

Since the successful draining of lake Hadra and the surrounding salt marsh this area of the city has undergone rapid urban development resulting in few remaining open spaces suitable for geophysical survey. However, the approximate location for the temple does fall over an area where access could be gained to three properties, the Port Authority bus park, the Elabrahimia school for girls at 17, Sharia Tutankhamun and the Ashraf el Khagha primary school at 15, Sharia Tutankhamun, where open ground surfaces were available to conduct key-hole geophysical surveys (Figure 1). Conditions in the three available areas varied but a number of factors compromised the potential success of geophysical prospecting techniques including the presence of standing buildings, parked vehicles and an unknown depth of made ground for the hard-standing within the bus park. Views of the three sites at the time of the surveys are provided in Plate 1, below.

Other geophysical work has previously been carried out in the vicinity at Chatby in the city's modern cemeteries, searching for remains associated with the earlier Royal Ptolemaic Cemetery (Gaber *et al.* 1999; Papamarinopoulos *et al.* 2003). This work focussed on the use of deep penetrating techniques such as electrical imaging and gravitometry accompanied by some ground penetrating radar. Whilst these techniques are able to detect large features at depth (as was appropriate in the cases of the cited studies), they are often not best suited to the resolution of smaller scale archaeological anomalies in the near subsurface. Furthermore, they often require larger open areas unobstructed by modern structures for their successful operation (for instance to have room to lay out a line of electrodes for an electrical imaging survey). Given the restricted nature of the areas available for the present study and the relatively smaller scale archaeological features that were expected at the sanctuary such as foundations of smaller buildings, a second objective of the project was to test the applicability of the geophysical techniques that would typically be used in the United Kingdom for the investigation of the shallow subsurface on urban brown-field sites.

Plate 1: Views of the survey locations and deposit depth. Top left: the Port Authority Bus Depot with EM survey in progress. Top right: The Elabrahimia School for Girls. Bottom left: The Ashraf el Khagha primary school. Bottom right: old piling at a nearby construction site to some 3-4m depth through the lacustrine deposits, illustrating the deposit depth.

Alexandria is largely built on a limestone ridge (Said 1962), however, in the Smouha district a substantial thickness of lacustrine deposits (some 2-4m) overlies the bedrock due to the presence of lakes Hadra and Hydra in this area until the comparatively recent past (see Plate 1, bottom right). The depth of these deposits was acknowledged as potential a problem, however, as remains were reported to still be visible on the surface in 1872, it was considered unlikely that they would, in the last 150 years, have become covered by a substantial depth of overburden.

At the time of the survey all three open areas exhibited a covering of sand with some evidence for concrete hard standings and rubble hardcore in places. A number of vehicles were parked on the bus depot site but, where possible, these were moved for the purposes of the survey.

Method

Given the urban nature of the site a Ground Penetrating Radar (GPR) survey was considered to be the most suitable technique to apply. The available ground surfaces were known to be unsuitable for earth resistance survey (due to the difficulty of overcoming extremely high contact resistances), although an electromagnetic survey with Slingram instrument seemed feasible and would provide a useful complement to the GPR data set. Regrettably, both the original operating console and a replacement unit supplied for the Noggin GPR were defective on arrival in Alexandria and considerable amount of time was spent resurrecting a working system.

Survey grids in all three areas were established using taped offsets from buildings and boundary walls. The locations of the grids were subsequently established to greater accuracy with the assistance of staff from the CEA using their mapping grade Global Positioning System (GPS). Figure 1 shows the locations of all the geophysical surveys conducted as part of the project at 1:1250 scale. The locations of a number of unmapped buildings within the bus depot were also recorded with the GPS and these have been indicated with blue hachures in the figure. It may be noted that there is a small discrepancy between the GPS mapped features and those on the 1991 map of the area. This is likely to be due to the greater accuracy that can now be achieved with GPS technology. The estimated location of the sanctuary boundary determined by map regression has been marked on Figure 1 in magenta.

Electromagnetic (EM) survey

A Geonics EM38 soil conductivity meter was used to make measurements with a vertical coil orientation at a 1m x 1m sample interval recording first the in-phase response (proportional to the magnetic properties of the site) and then a repeated to obtain the quadrature-phase (proportional to the conductivity of the site). This instrument has a depth sensitivity of approximately 1.5m and should be able to detect both magnetic features (for example buried hearths) and significant contrasts in soil conductivity/resistivity (for example a buried masonry wall or a more moisture retentive ditch). Surveys were conducted with this instrument in the Port Authority bus park and the Elabrahimia school for girls but time and access constraints precluded its use at the the Ashraf el Khagha primary school.

To correct for instrument drift the in-phase EM dataset from the bus park was processed to zero the median of each walked traverse. In addition owing to the high number of sharp spike-like readings caused by metallic objects, the data set was despiked using a 1m x 1m median filter, replacing any reading differing from the local median by more than 1.4 parts per thousand (ppt) with that local median. To enhance weak, possibly significant features within the data set it was further processed using the Wallis contrast enhancement algorithm (Wallis 1976) with a window width of 15m and an edge-to-background ration of 0.8. The quadrature-phase data was treated in the same way although it was not necessary to zero the median of each traverse for this data set. The results are depicted, before and after contrast enhancement in Figure 5 at 1:1000 scale.

The in-phase and quadrature phase data sets collected from the Elabrahimia school for girls were less affected by modern metallic debris and it was only necessary to enhance contrast using the Wallis algorithm. These results are depicted in Figure 6 at 1:750 scale.

The in-phase results from both areas are depicted superimposed on the map of the area in Figure 2 at 1:1000 scale and a corresponding depiction of the quadrature phase data is provided in Figure 3.

Ground Penetrating Radar (GPR) survey

This was conducted with a Sensors & Software Noggin integral GPR system utilising a 250MHz centre frequency antenna. The data was collected at a sample interval of 0.05m x 1.0m through a 60ns time window. These parameters were partially constrained by instrument failure in the field that restricted the time available for data acquisition.

Successful GPR survey is highly dependent on local site conditions and in this case the presence of high conductivity clay deposits, from both the former salt marsh and the saline lake Hadra, will have attenuated the radar wave front in the subsurface. Whilst GPR survey may still be viable under high conductivity conditions, the depth of penetration may often be restricted. The precise depth to significant reflectors can be obtained from the time taken to receive the reflection after the initial pulse is sent into the ground and an estimate of the radar velocity under the ground. Here, an estimate was obtained from the analysis of point reflectors producing hyperbolic responses that suggested a radar velocity of 0.056m/ns.

Post acquisition processing involved the adjustment of time-zero to coincide with the true ground surface, removal of any low frequency transient response (dewow), noise removal and the application of a suitable gain function to enhance late arrivals.

Owing to antenna coupling of the GPR transmitter with the ground to an approximate depth of $^{\lambda}/_{2}$, very near surface reflection events should only be detectable below a depth of 0.112m, if a centre frequency of 250MHz and a velocity of 0.056m/ns are assumed. However, the broad bandwidth of an impulse GPR signal results in a range of frequencies to either side of the centre frequency which, in practice, will record significant near-surface reflections closer to the ground surface. Such reflections are often emphasised by presenting the data as amplitude time slices. In this case, the time-slices were created from the entire data set, after applying a 2D-migration algorithm, by averaging data within successive 2ns (two-way travel time) windows (David and Linford 2000; Sensors and Software 1996). Each resulting time slice, illustrated as a greytone image in Figures 7 and 8 at 1:1000 scale, represents the variation of reflection strength through successive ~0.056m intervals from the ground surface. The 20-22ns time slices from both the areas surveyed with the GPR are depicted, superimposed on a map of the area, in Figure 4 also at 1:1000 scale.

Results

Graphical summaries of significant anomalies are provided in Figure 9 at 1:1000 scale and a detail of the anomalies in the bus depot area is included at 1:500 scale in Figure 10. Codes in square brackets in the text below refer to marked anomalies on these figures.

Port Authority Bus Depot

Electromagnetic (EM) survey

In addition to the interpretation plans, EM results from this area are plotted in Figure 5 and superimposed on the map in Figures 2 and 3.

EM survey within the bus depot has been greatly affected by the presence of modern small-scale metallic debris over the survey area resulting from its use for vehicle parking and repair. In addition it was necessary to work around vehicles that were still parked on the area at the time of the survey. These have resulted in a number of high intensity in-phase anomalies towards the centre of the area that have been marked as modern disturbance in Figures 9 and 10. A diagonal, linear high intensity anomaly is also evident in the NE corner of the in-phase (IP) survey [IP1] and it is also evident in the quadrature-phase (QP) data. Visual inspection suggested that this must result from a buried supply pipe leading to a water hydrant nearby. Some further disturbance caused by recent construction has also been marked on Figure 9 at the W edge of the dataset.

Two fainter, linear anomalies of raised magnetic intensity are evident at [IP2] forming a right angle. It is possible that these represent infilled ditches where anthropogenic activity has enhanced the magnetic susceptibility of the ditch fill with respect to the surrounding soil. However, their alignment with the modern boundary walls of the site might suggest that they are relatively recent features.

To the SE a collection of very faint linear anomalies of negative intensity may just be discerned [IP3]. Whilst these are too weak to be interpreted with any certainty, it is possible that they represent buried masonry with a magnetic susceptibility slightly lower than that of the surrounding soil. A number of faint linear low conductivity QP anomalies also occur in the vicinity [QP1] although they do not coincide with the IP anomalies. It is thus possible that these groups of anomalies represent the evident of former structures in this area, although the responses are extremely weak if this is the case. It must also be cautioned that they may be the result of fairly recent activity as a number of covered hard-standings existed in proximity to these anomalies it is possible that others have been constructed here in the past.

At the SE corner of the survey another group of low intensity IP anomalies may be discerned [IP4]. These may have a similar cause to those at [IP3] and their rectilinear outline is certainly suggestive of the footings of a structure. However, they are in close proximity to a modern concrete platform and it is possible that they relate to its construction rather than being of archaeological origin.

Two further very faint linear low conductivity (QP) anomalies have been marked [QP2 and QP3]. It is possible that they represent the remains of a boundary wall and joint to form a corner to the S of the survey area. However, they are so faint that it is not possible to make this interpretation with confidence.

GPR survey

In addition to the interpretation plans, GPR results from this area are plotted in Figure 7 and superimposed on the map in Figure 4.

A high degree of noise is evident in the GPR data from the bus depot site (Figure 7) particularly in the near surface time slices. This has largely been caused by the use of rubble to create a firmer surface to take the weight of heavy vehicles. Metallic debris discarded during the repair of these vehicles has also created a distribution of near surface point reflectors resulting in a high degree of random scattering to the GPR signal. The signal also appears to attenuate fairly rapidly with depth and little coherent information can be discerned at return times greater that 32ns (~0.95m beneath the surface). Such attenuation would be consistent with the highly conductive subsurface expected in the area of a former salt marsh and EM measurements indicate a mean conductivity of $49\pm16mSm^{-1}$ over the site.

A number of low amplitude anomalies in the GPR data set can be discounted as they correspond with areas indicated to be modern disturbance by the EM survey. In at least one case, towards the centre of the site, both instruments appeared to be responding to an area of surface water resulting from heavy rain. However, at [GPR1] a rectilinear low amplitude anomaly can be discerned in returns between 20 and 26ns (~0.56m to 0.73m) and this appears to surround a sub-rectangular area of strong reflection. Given its form, it is possible that this anomaly indicates the presence of structural remains buried at a depth of ~0.5m. However, it must be cautioned that a similar response is evident in the very near surface returns between 0 and 4ns suggesting that the anomaly from 20 to 26ns may be a response to the bottom of a feature that extends to the very near surface, in which case it is likely to be of recent origin. In addition, the low amplitude nature of this response would not, necessarily, indicate the presence of in situ structural building remains. There is some evidence for a high amplitude rectilinear reflector in the vicinity of [GPR1] at [GPR2], but this is only evident in a single, near surface time slice between 6 and 8ns (0.17 to 0.22m) suggesting a less significant causative feature.

At [GPR3] a tentative anomaly describing a right angle and ~1m wide may just be discerned that is most clearly evident in returns between 8 and 10ns. Whilst, the form of this anomaly is suggestive of a buried wall footing, its extremely low amplitude relative to the amount of noise in the GPR signal and shallow depth (0.22 to 0.28m) makes any definitive interpretation impossible.

Elabrahimia school for girls

Electromagnetic (EM) survey

In addition to the interpretation plans, EM results from this area are plotted in Figure 6 and superimposed on the map in Figures 2 and 3.

This site was much less affected by surface metallic debris than the bus depot and as is clear from the much smoother background responses in both the IP and QP datasets. A number of very clear anomalies have been detected as both IP and conductivity anomalies. In particular a very strong linear anomaly, showing most clearly as a low conductivity structure in the QP data set [QP4], runs southeast through the survey area before turning through 45° just before the SE edge of the survey area. Unfortunately, all the anomalies marked in this survey coincided with drain covers or concrete platforms visible on the surface and the linear anomaly [QP4] runs directly between several man-hole covers indicating that it is almost certainly caused by a modern utility pipe.

As the evidence from the EM survey suggested that there was little ground beneath the playground of the Elabrahimia school that was not obscured by modern services, it was decided, given restrictions on the time available, not to attempt GPR survey here.

Ashraf el Khagha primary school

GPR survey

In addition to the interpretation plans, GPR results from this area are plotted in Figure 8 and superimposed on the map in Figure 4.

Only GPR data was collected from this site where the sand covered playground area provided good conditions for the survey. Some minor impediments included a pair of metal goal posts and some mature trees planted along the perimeter walls to the south and east. A diffuse area of higher amplitude response [GPR4] runs approximately north south across the site between 14 and 24ns (0.39 to 0.67m). This may well represent an area of more compacted ground beneath the initial layer of sand possibly associated with a number of fragmented high amplitude responses [GPR5-7] found at a similar depth. The significance of [GPR5-7] is difficult to ascertain due to the incomplete nature of these responses. However, anomalies to the west [GPR5], close to the location of the school toilets and perimeter with Sharia Tutankhamun, may well indicate the location of modern services.

Perhaps of greater significance are a number of linear anomalies [GPR8-11], including a double linear response [GPR11] that appears to head towards the privately owned parcel of land to the south east. Precise interpretation of these anomalies is difficult, as they are not fully described within the available survey area and are recorded between 12 and 28ns (0.34 to 0.73m) that may be too shallow for architectural remains. However, the nature of the anomalies does not, necessarily, suggest modern services and later reflections in the data (from more deeply buried features) may have been attenuated by the high conductivity subsoil at the site.

Further circumstantial evidence from the historical map regression places the site within the approximate location of the temple with no indication from available aerial photographs of any other buildings preceding the development of the school complex in the 1950s. This may well rule out the presence of any previous development of the site that might otherwise account for the presence of service pipes on this area.

Conclusions

Geophysical survey within an urban context is often compromised by the unavailability of suitable open areas and the presence of extant structures. The response to significant archaeological remains is often quite subtle and may be entirely obscured by the physical contrasts exhibited by more recent, overlying deposits. In the present case the most practical geophysical technique to apply was Ground Penetrating Radar using a relatively low centre frequency antenna to overcome the attenuating effect of the high conductivity sediments that developed within an area of former salt marsh. A complementary electromagnetic survey was also conducted to record the variation of magnetic and soil conductivity properties over the site with the aim of eliminating responses due to modern services.

Unfortunately, access was only possible to three properties in the vicinity of the suspected temple and whilst a number of geophysical anomalies were identified none of these are fully described due to the key-hole nature of the survey, thus limiting the confidence that may be placed on their interpretation. Perhaps the most significant anomalies are found in the play ground of the Ashraf el Khagha primary school in an area that seems to have escaped more recent intervention. These anomalies together with the concentration of (recti)linear responses found in the Port Authority Bus depot provide the most likely candidates for further investigation. However, some attempt to establish the precise course of modern services from existing buildings and any former structures on both sites would be prudent prior to any invasive excavation.

Whilst other areas of the site are potentially available for geophysical survey, ground conditions observed during the current field work indicated mainly metalled or tiled surfaces with the exception of a gravel and sand compound adjoining the Ashraf el Khagha primary school to the south. Such surfaces do not necessarily preclude the application of further geophysical survey but they will complicate the interpretation of results and any identification of archaeological targets is likely to entail a degree of uncertainty. Hence, some limited invasive investigation is recommended first to establish the origin of the anomalies reported here and the nature of any associated archaeological remains. This would allow the geophysical methodology to be refined, for example by deploying a lower centre frequency antenna if evidence for substantial wall footings were suspected below the depth of signal attenuation revealed by the current survey.

One aim of the survey was to test the applicability of geophysical techniques appropriate for the detection of smaller scale archaeological features that might be expected at this site. This is of course impossible to fully assess without testing the identified anomalies against excavation but it is encouraging that both the EM and GPR techniques could be deployed under the difficult circumstances posed at this site. In particular, the very limited time window allowed for access to avoid disruption to lessons at the two school sites required instrumentation optimised for rapid data acquisition. The cart mounted integral Noggin GPR proved highly capable in this respect and was also a practical system for transport to the site via air freight from the UK. Unfortunately, in this instance the Noggin Plus system was compromised by the failure of two DVL data logging units and the inability to operate the instrument directly from software via a laptop PC.

Surveyed by:	N Linford P Linford	Date of survey:	1-3/11/2004
Reported by:	N Linford P Linford	Date of report:	30/04/2005

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List of enclosed figures

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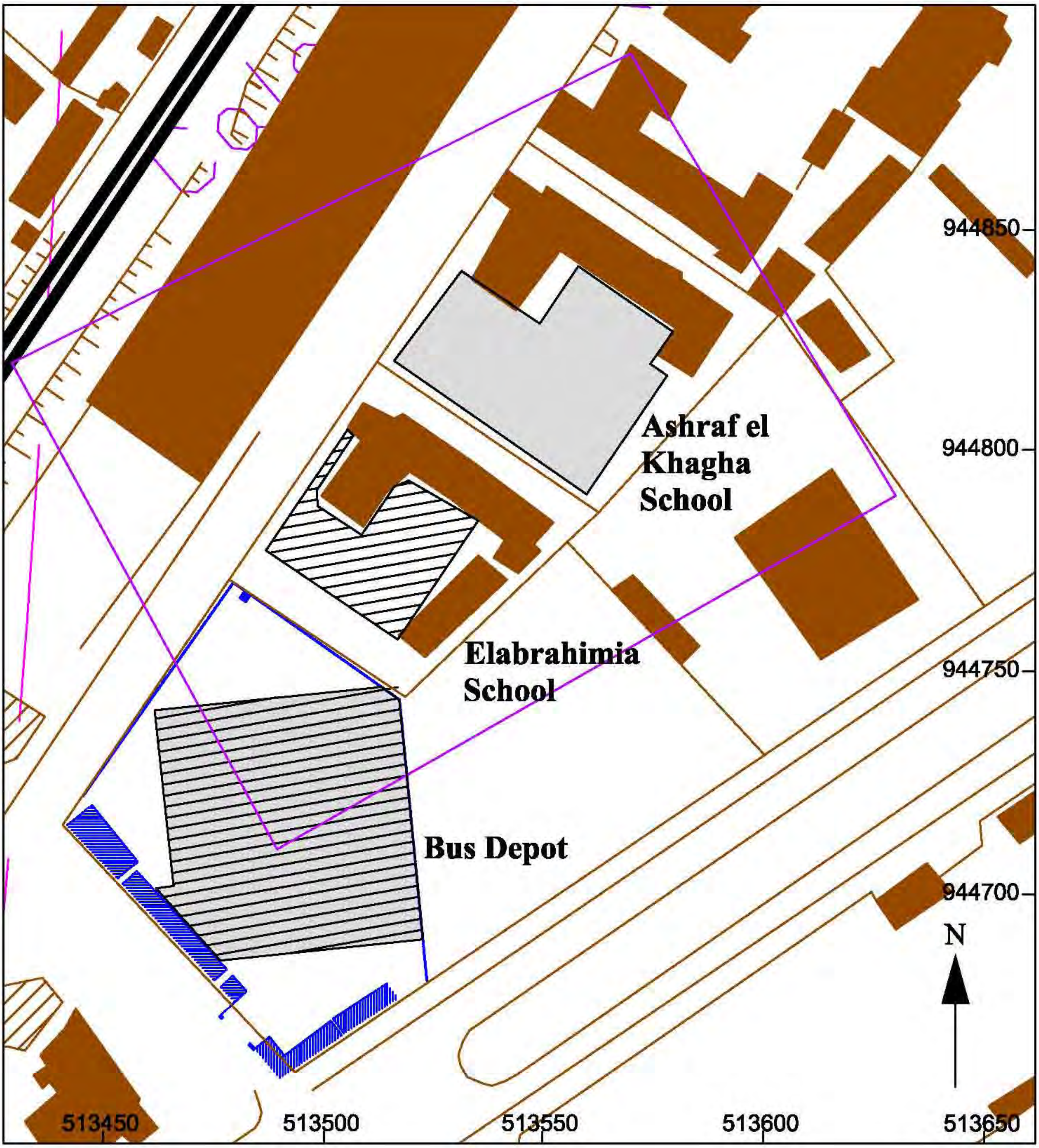
Figure 1) Smouha, Alexandria, location of geophysical surveys, November 2004.



Area surveyed with GPR

Standing structure marked on map.

Area surveyed with conductivity meter.

Unmapped structures recorded with GPS.

Estimated location of temple boundary from map regression.

0 60m
1:1250

Figure 2) Smouha, Alexandria, in-phase EM data, November 2004.

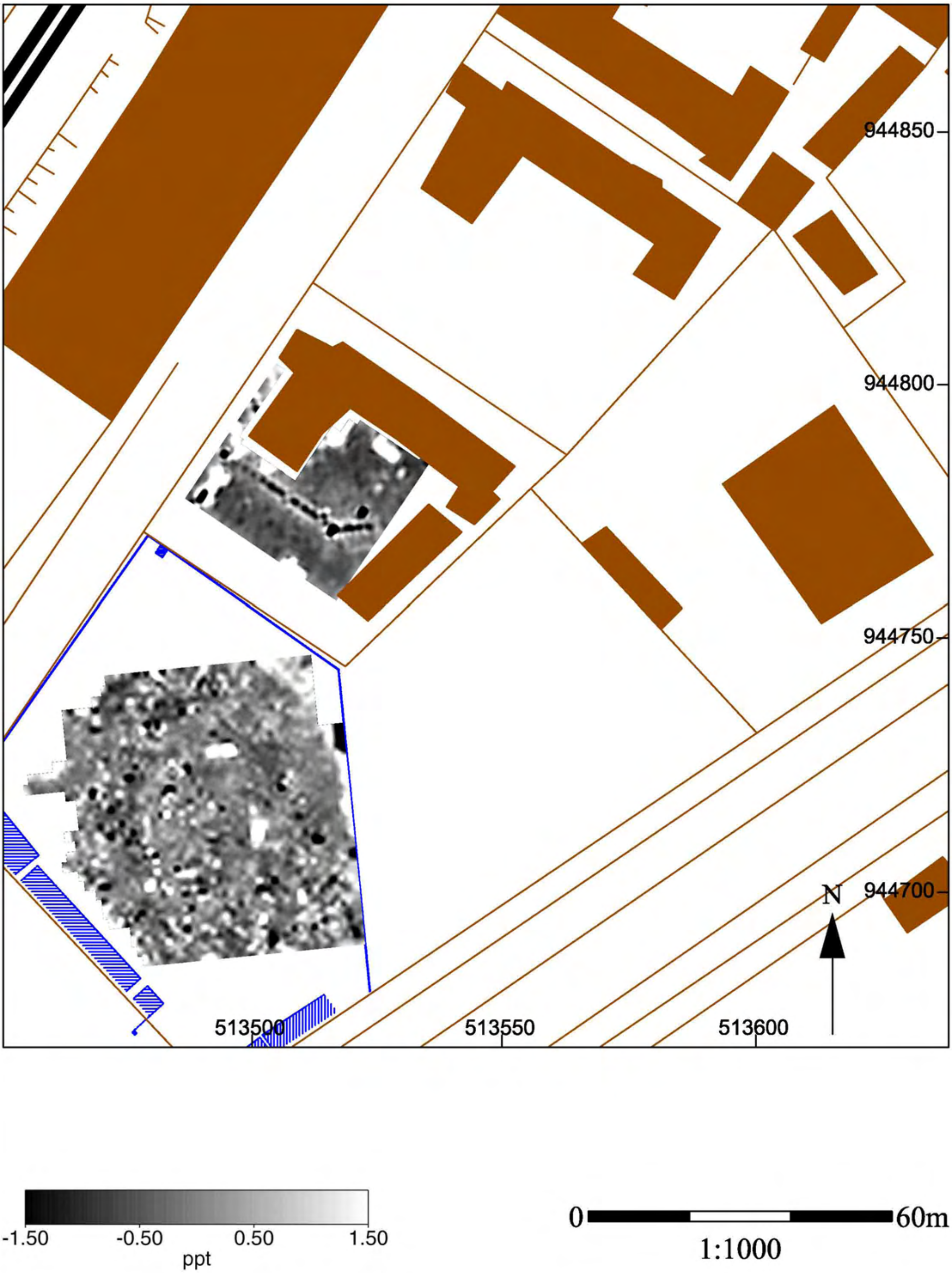


Figure 3) Smouha, Alexandria, conductivity (quadrature-phase) EM data, November 2004.

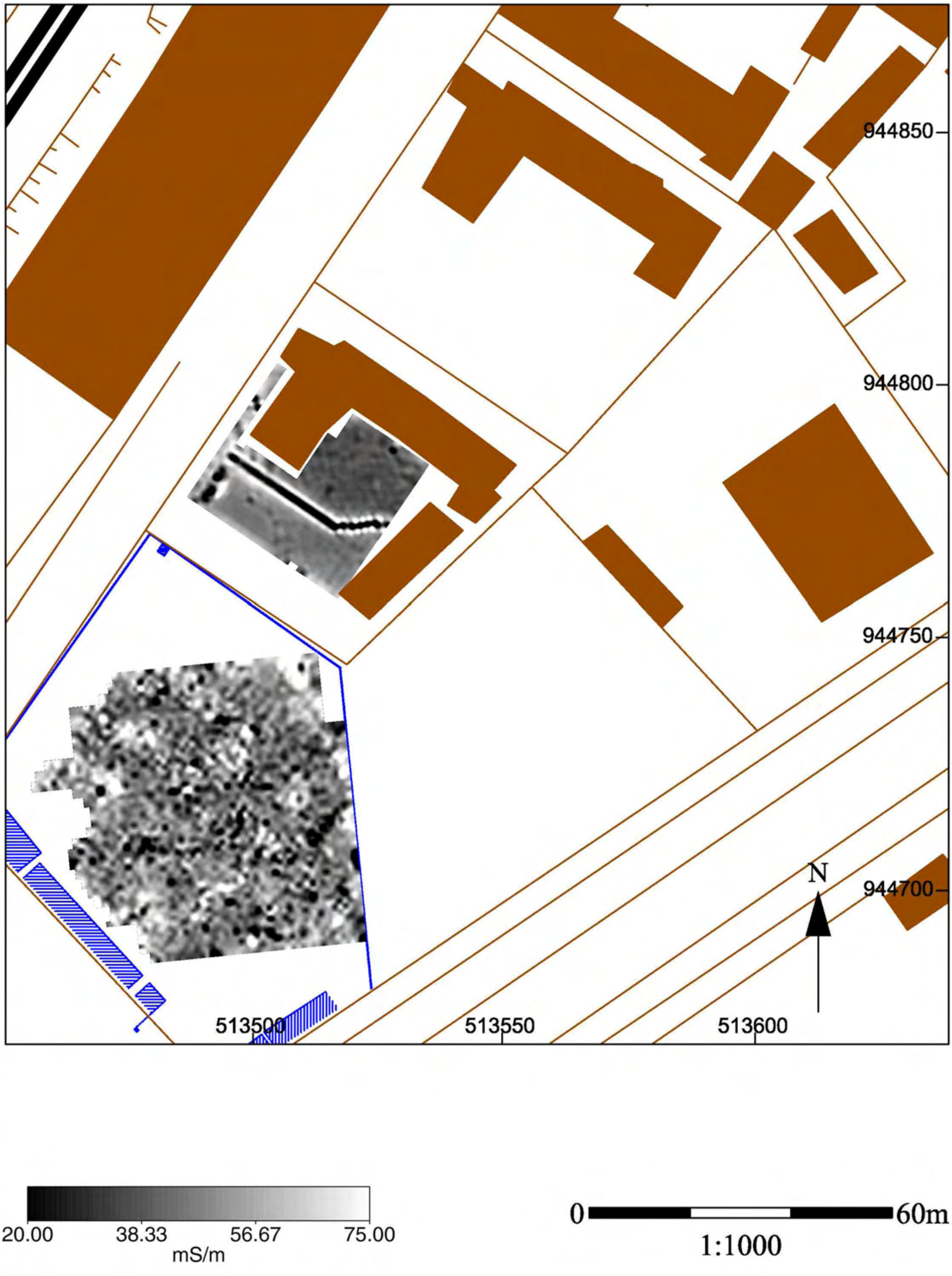
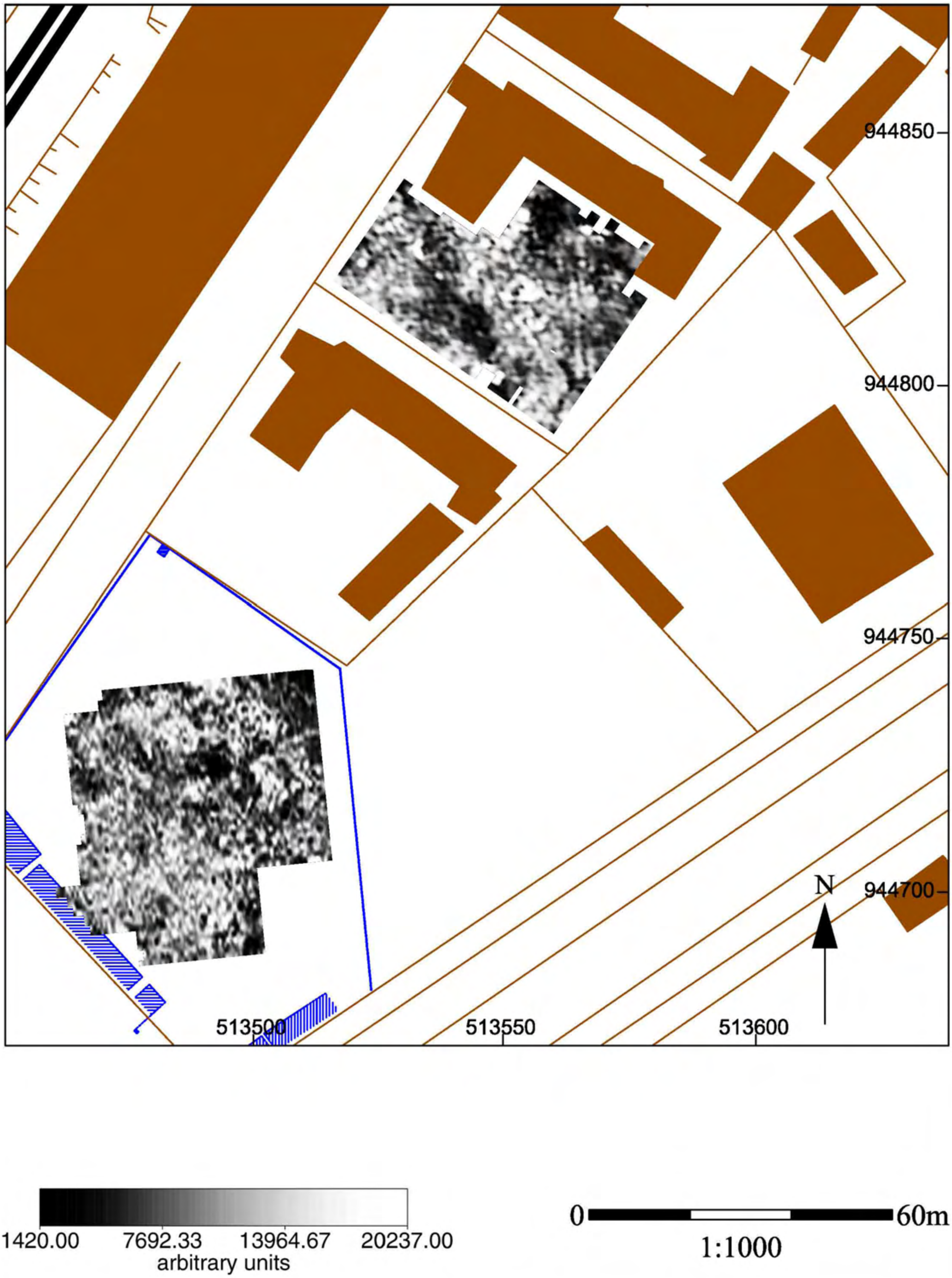
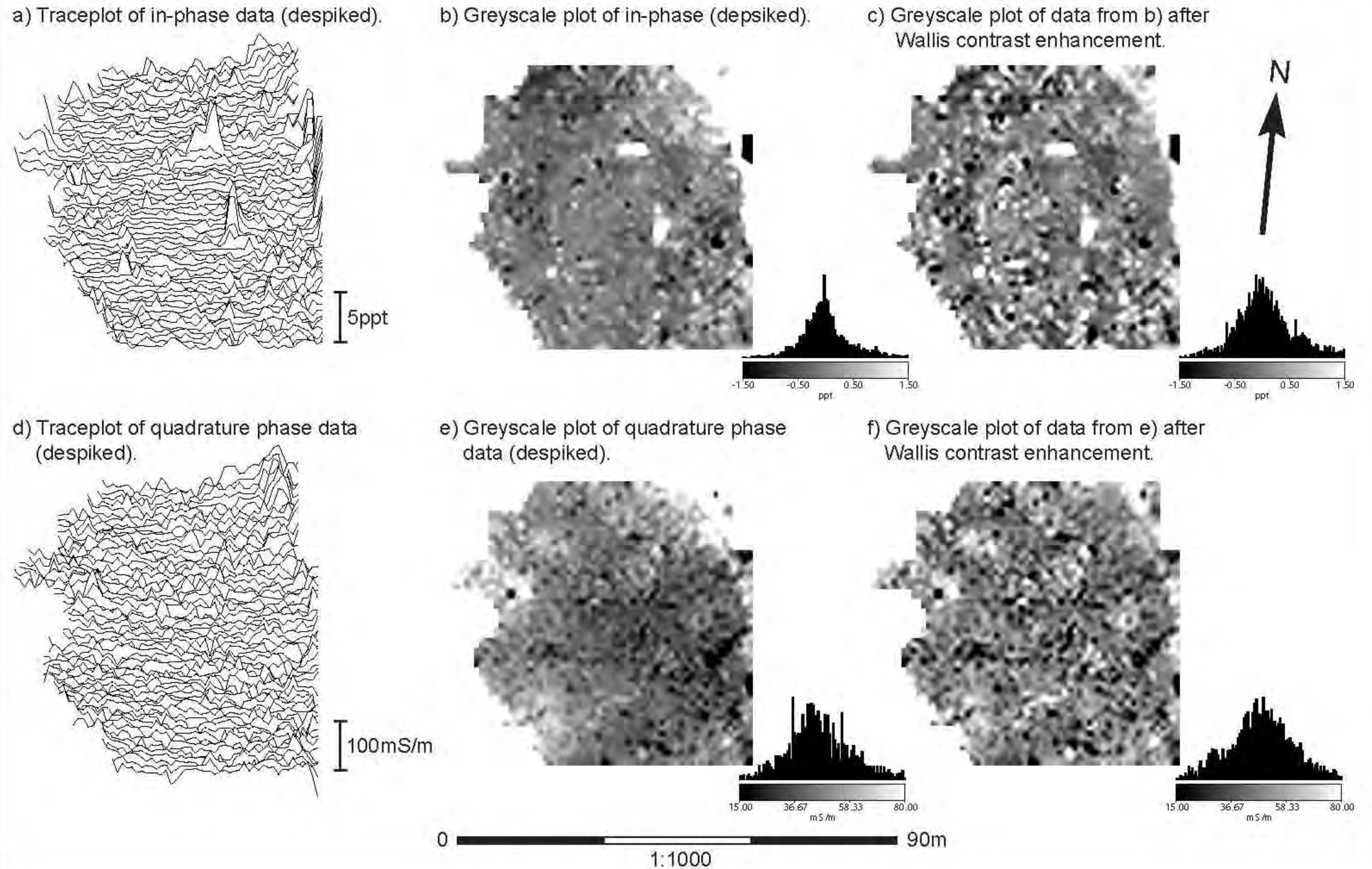


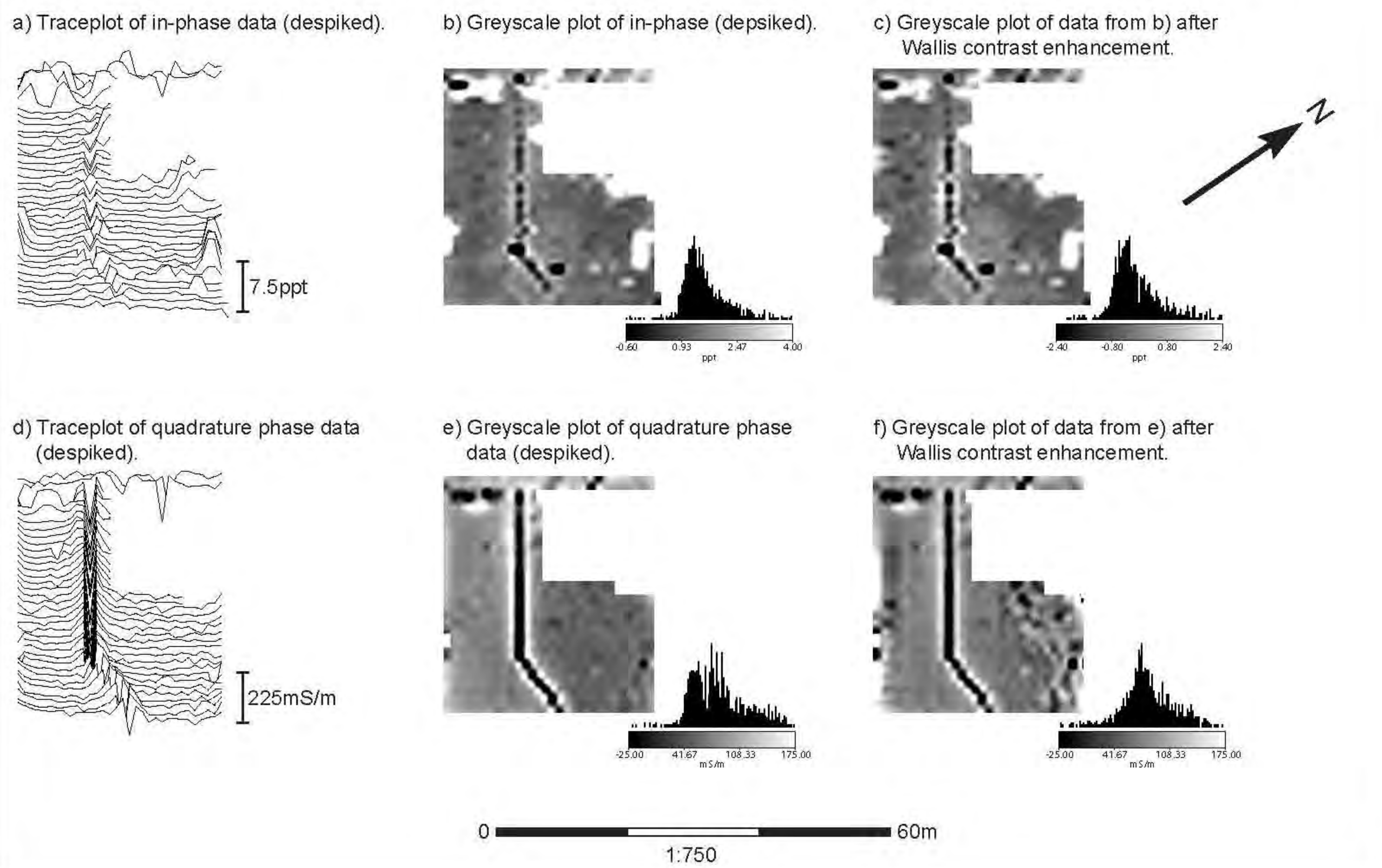
Figure 4) Smouha, Alexandria, GPR data, 20-22ns time slices (~0.6m depth), November 2004.



PORT AUTHORITY BUS DEPOT, Smouha, Alexandria, Electromagnetic survey, November, 2004. *Figure 5*

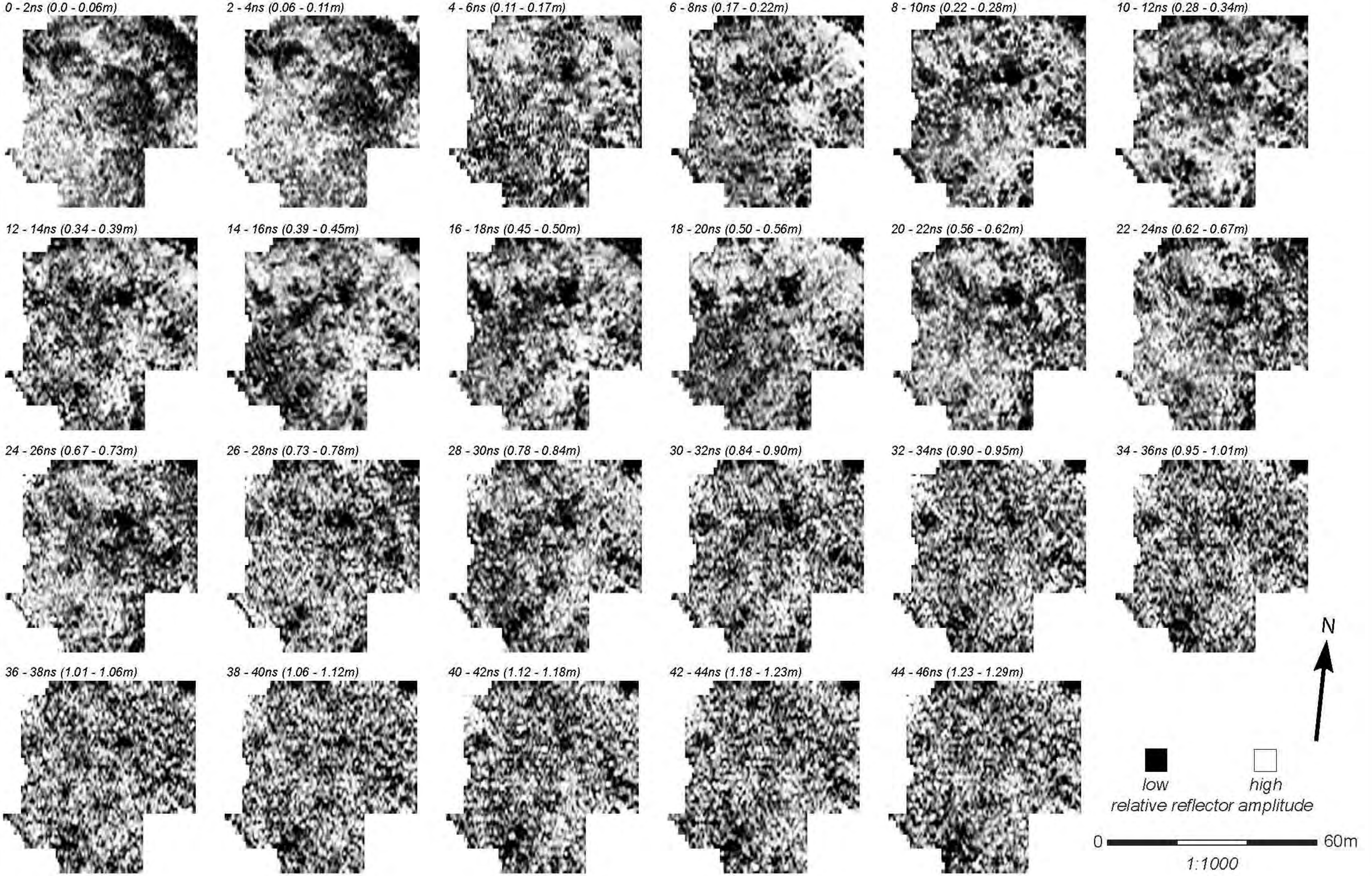


ELABRAHIMIA SCHOOL FOR GIRLS, Smouha, Alexandria, Electromagnetic survey, November, 2004. *Figure 6*



PORT AUTHORITY BUS DEPOT, Smouha, Alexandria.
GPR Amplitude Time Slices 250MHz data

Figure 7



ASHRAF EL KHAGHA PRIMARY SCHOOL, Smouha, Alexandria.
GPR Amplitude Time Slices 250MHz data

Figure 8

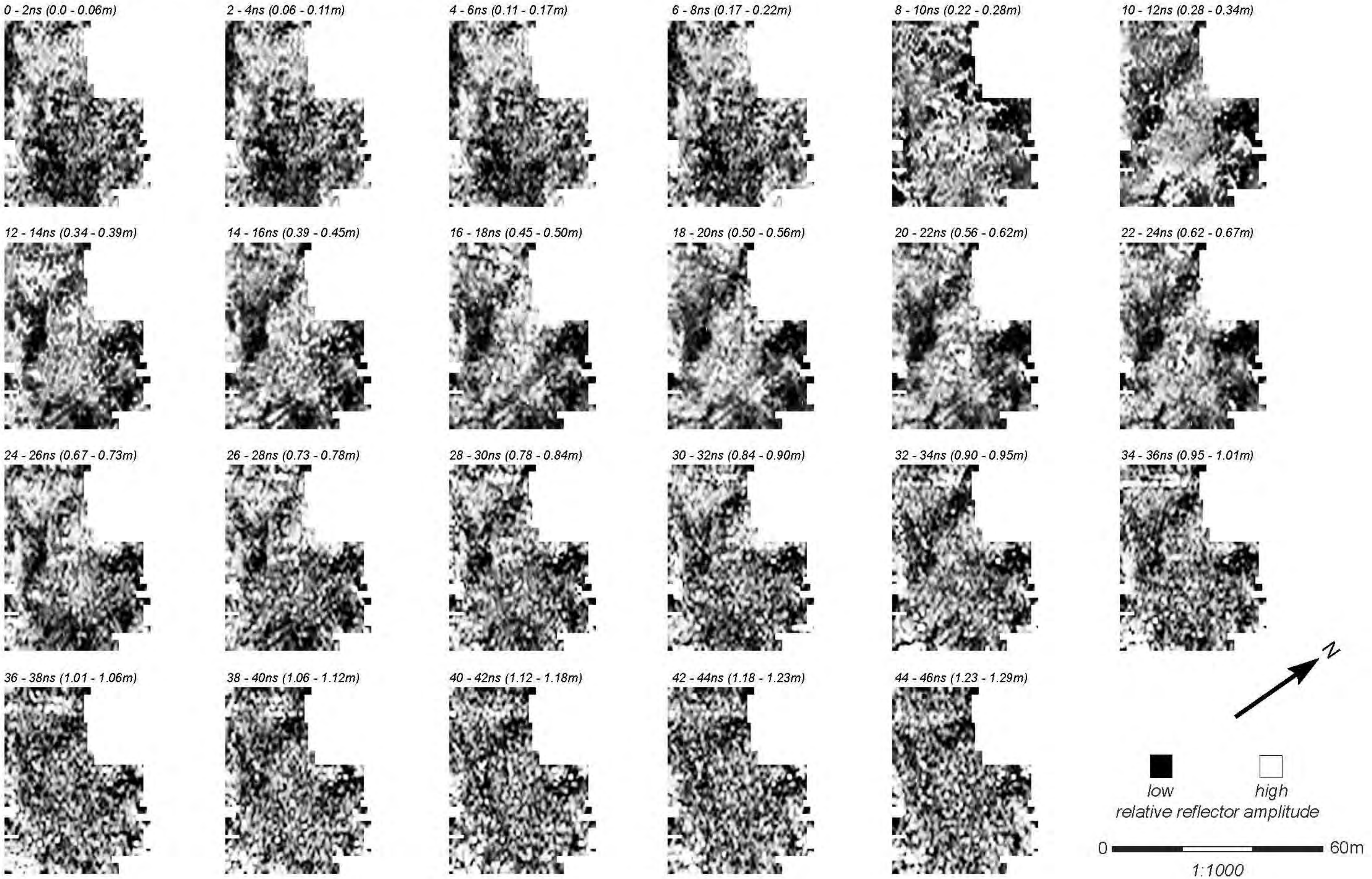
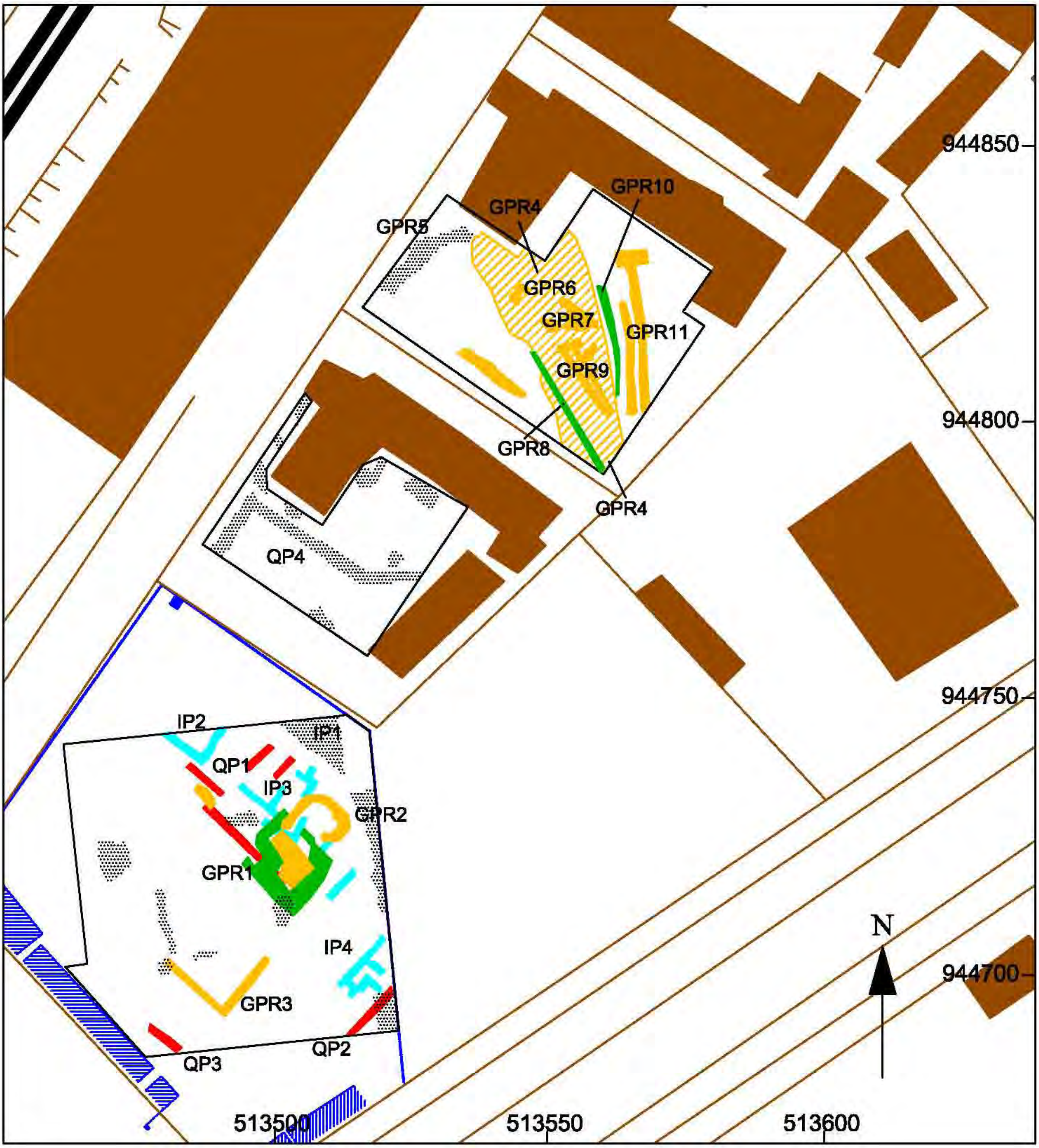


Figure 9) Smouha, Alexandria, interpretation of geophysical anomalies, November 2004.



Key

In-phase EM anomaly
Conductivity anomaly
GPR positive anomaly
GPR negative anomaly
Diffuse area of raised GPR reflectance
Modern disturbance

0 60m

1:1000

Figure 10) Smouha, Alexandria, Port Authority Bus Depot, interpretation of geophysical anomalies, November 2004.

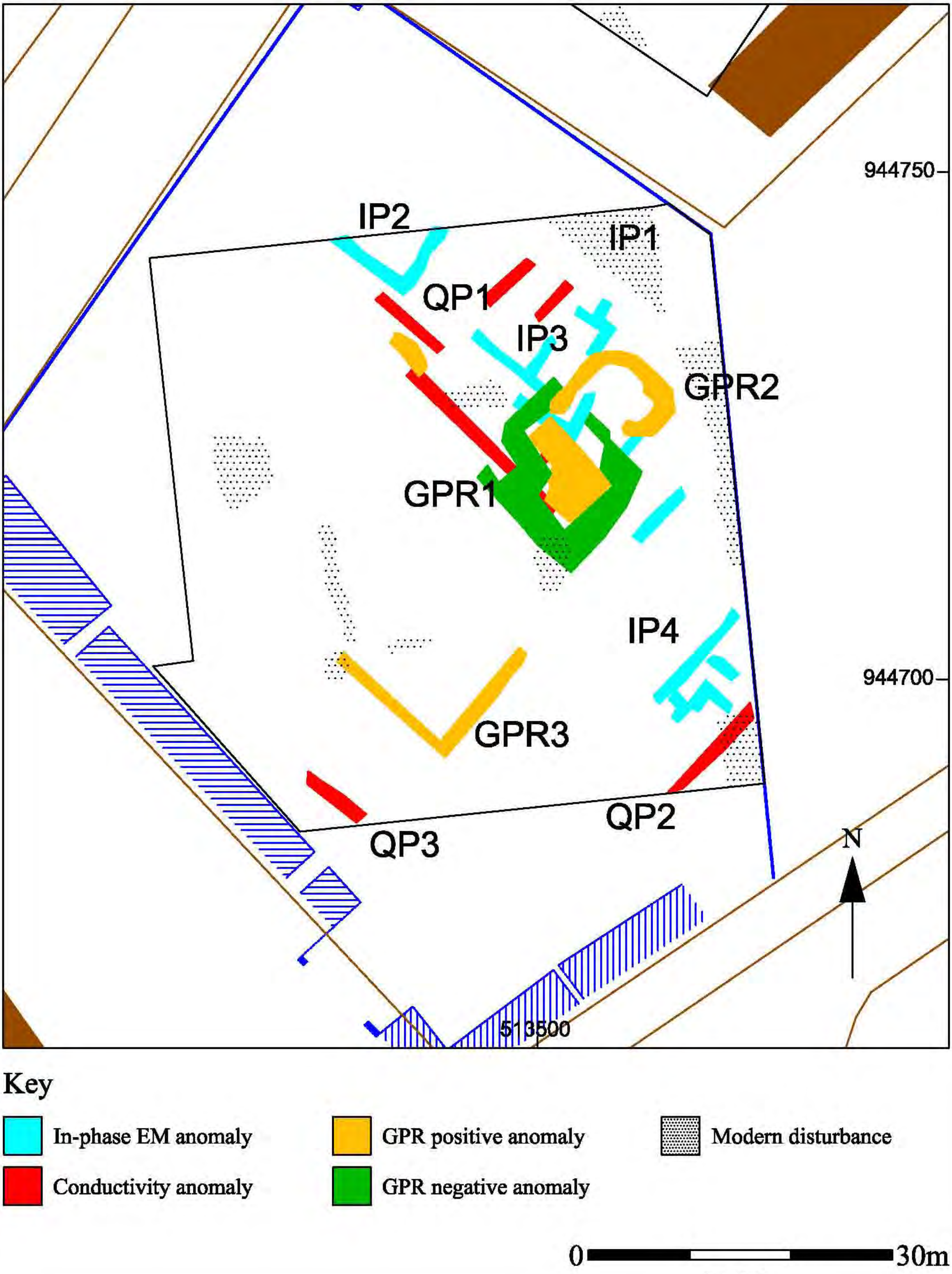


Figure 11) Elabrahimia and Ashraf el Khagha schools, Smouha, Alexandria, interpretation of geophysical anomalies, November 2004.